INCLUSIVE NEUTRAL PARTICLE PRODUCTION[*]

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ABSTRACT

Results of recent inclusive neutral particle production experiments are compared to existing experimental results. These experiments range from 15 GeV/c to 2000 GeV/c in laboratory beam momentum and use π^-, π^+, p and $\bar{p}$ beams.

In this report I shall give results of seven experiments on inclusive neutral particle production. These are the papers[1-7] submitted to the Seattle conference of the APS Division of Particles and Fields. In Table I provide general information about these experiments. Five of these experiments were performed in a bubble chamber with hydrogen as a target. Two of the experiments were counter experiments; one performed at Fermilab and one at the CERN ISR. I shall restrict my discussion to total inclusive cross section, dependence on charge multiplicity and x and P_T^2 inclusive distributions.

TABLE I
Experiments Submitting Papers

Institutions	Beam	Momentum (GeV/c)	Principle Device	Particles Produced
Michigan State U – Tufts – Fermilab	$\bar{p}$	14.75	BNL 80" BC	γ, K^0, Λ^0
Columbia – SUNY (Binghampton)	π^+	15	SLAC 82" BC	π^0, K^0, Λ^0, $\bar{\Lambda}^0$
Michigan State U – Cambridge – Fermilab	$\bar{p}$	100	Fermilab 30" BC	γ, K^0, Λ^0, $\bar{\Lambda}^0$
Fermilab – Florida State U	π^-	250	Fermilab 15' BC	K^0, Λ^0, $\bar{\Lambda}^0$
ANL – Kansas – SUNY (Stoneybrook) – Tufts	p	300	Fermilab 15' BC	γ
Wisconsin – Michigan – Rutgers	p	300	Fermilab Counter Exp.	K^0, Λ^0, $\bar{\Lambda}^0$, Ξ^0
UCLA – SACLAY	p	653	CERN ISR	Λ^0
AACHEN – UCLA – CERN	p	2050	CERN ISR	Λ^0

The inclusive cross section for the production of a particle is the cross section for production of that particle plus anything else. Figure 1[8] shows the inclusive cross section for the production of π^O by pp and $\overline{p}p$ interactions as a function of beam momentum. For low energy experiments these cross sections are determined by seeing both photon conversions of the π^O, but at high energies where only a single photon conversion is observed, $\sigma(\pi^O)$ is implied from the cross section for production of photons. The cross section for π^O production by pp interactions increases rapidly and approximately linearly with increasing log p_{beam}. It has been observed experimentally that $\sigma(\pi^O) \approx \frac{1}{2}$ $[\sigma(\pi^-)+\sigma(\pi^+)]$. The production of π^O for $\overline{p}$ induced interactions is larger than the π^O production for the p induced interactions at the same energy, however the difference tends to get smaller at higher energy.

In Figure 2 the $K_S, \Lambda^O, \overline{\Lambda}^O$ inclusive cross production sections[8] for pp interactions are shown. Defining low energy to be interactions with less than 50 GeV/c laboratory momentum, one sees that $\sigma(pp \rightarrow \Lambda^O X)$ is greater than $\sigma(pp \rightarrow K_S^O X)$ in the low energy region. In the high energy region the K_S^O production cross section overtakes the Λ^O production cross section. In the high energy region the Λ^O cross section is approximately constant independent of incident momentum. The K_S^O production cross section increases linearly with log P_{Lab}. Points in the ISR energy region have been included to show that these trends continue. An ISR experiment producing Λ^O at equivalent lab momenta of 652 GeV/c and 2050 GeV/c is included in the data. As K_S^O production from ISR experiments is not presently available, estimates from K^+ and K^- cross sections were made. The rising K_S^O cross section and constant Λ^O cross section may be explained by the domination of the K_S^O production by central region processes such as $K^O\overline{K}^O$ production whereas the Λ^O production is dominated by fragmentation processes like $K\Lambda^O$ production. The non-domination of the Λ^O cross section by the $\Lambda^O\overline{\Lambda}^O$ contribution to the Λ^O cross section is confirmed by the size of the $\overline{\Lambda}^O$ production cross section. Comparing the K_S^O production cross section to the π^O cross section we see that the ratio is approximately 5% in the high energy region.

The $K_S^O, \Lambda^O, \overline{\Lambda}^O$ production cross sections for π^-p interactions are shown in Figure 3. In the high energy region we find that the ratio of Λ^O production by π^-p to pp is ~0.5 where the corresponding ratios for K_S^O is 0.57. If we assume factorization of the vertices and that Λ^O production is predominately associated to the proton vertices, then we might expect $\sigma(\pi^-p \rightarrow \Lambda^O X)$ to be 1/3 of $\sigma(pp \rightarrow \Lambda^O X)$. There is of course some Λ cross section associated with $\Lambda^O\overline{\Lambda}^O$ production which is not in the fragmentation region. To explain this with $\Lambda^O\overline{\Lambda}^O$ production we would want a larger $\overline{\Lambda}^O$ cross section than is observed. The K_S^O production cross section ratios can be explained. If the K_S^O cross section was associated only with central region processes one would expect the ratio of K_S^O production cross sections to be equal to the ratio of inelastic cross sections (~0.63), however if there are proton fragmentation processes such as $K_S^O\Lambda^O$ production, one would expect a lower ratio since there are two proton vertices in pp interactions. Figure 4a and 4b show the cross sections for K_S^O and Λ^O production when compared to pp interactions. The lower Λ^O cross section may be associated to the presence of a single proton for the

p̄p interactions.

Reactions that produce neutral particles also produce charged particles. The correlation of the number of charged particles with the various kinds of neutral particles are of interest. Figures 5 and 6 show $<n_{K_S}{}^0>$ and $<n_{\Lambda^0}>$, the average number of $K_S{}^0$ and Λ^0 per inelastic collision, as a function of n_-, the number of negative charged prongs. Looking at the pp data we see that $<n_{K_S}0>$ is low for low multiplicity events, rising and possibly tapering off at higher multiplicities. One might expect $K_S{}^0$ to increase with n_- in a manner similar to π^0, however with a lower slope because of the larger $K_S{}^0$ mass. The tapering off at higher multiplicity would be due to diminishing availability of energy. We find that $<n_{\Lambda}{}^0>$ is consistent with being independent of multiplicity, as would be expected if the Λ^0 production were dependent on the fragmentation proton.

The inclusive differential cross section with respect to $x \equiv P_L{}^{cm}/P_{L_{max}}{}^{cm}$ and $P_T{}^2$ reveal features about the interactions. Figure 7a and 7b show the invariant cross section $F_1(x)$ for $K_S{}^0$ and Λ^0 production by π^-p interactions at 18.5 GeV/c[10] and 250 GeV/c[4]. The $F_1(x)$ distribution for $K_S{}^0$ production is slightly assymetric in π^-p interactions since there is no $K_S{}^0\Lambda^0$ produced at the beam fragmentation vertex as with pp interactions. In the central region, $|x|<0.3$, the 250 GeV/c data is higher than the 18.5 GeV/c data indicating that scaling in this region has not been achieved at 18.5 GeV/c. The fragmentation region is consistent with scaling. The invariant differential cross section with respect to $P_T{}^2$ seems roughly exponential for $K_S{}^0, \Lambda^0, \bar{\Lambda}^0$ production. Figure 8 shows $<P_T>$ for various beam energies, beam particles and produced particles. As different experiments display their results in different manners it was necessary to estimate $<P_T>$ from $<P_T{}^2>$, $<1/P_T{}^2>$, etc. Thus, data points in this graph should be considered approximate, however certain trends are evident, $<P_T>$ is not very dependent on beam energy or beam particle, but heavier mass produced particles seem to have larger values of $<P_T>$.

In Figure 9 data is shown from the Wisconsin-Michigan-Rutgers experiment.[6] The ratio of the $\bar{\Lambda}$ to Λ is plotted against P_{Lab}. $X = 0$ corresponds to about $P_{Lab} = 12$ GeV/c where one sees that $\bar{\Lambda}/\Lambda \approx 1$, verifying that Λ produced in that region are associated to $\Lambda\bar{\Lambda}$ production. This same experiment sees Ξ^0 and $\bar{\Xi}^0$ but their yields are preliminary at this point. The Ξ^0 yield is probably less than 1% of Λ^0 yield.

To conclude I would like to say that a large amount of data exists for single strange particle measurements. An interesting direction for new experiments to move is to study multiple production of strange particles (in the 15-foot Bubble Chamber, for example) and to study correlations and rapidity distributions of neutrals along with charged mesons.

REFERENCES

1. Study of K^0 and Λ^0 and Their Excited States in 15 GeV/c p̄p Interactions; Morris et al. Abstract submitted to this conference.

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2. Study of Inclusive K^O,Λ,$\bar{\Lambda}$, and π^O Production in 15 GeV/c π^+p Interactions; Baltay, et al. Abstract submitted to this conference.

3. Analysis of Antiproton Reactions at 100 GeV/c; Whitmore, et al. Paper submitted to this conference.

4. Neutral Strange Particle Production in π^-p Interactions at 250 GeV/c; Bogert, et al. Paper submitted to this conference.

5. Preliminary Study of Inclusive Photon Production from 300 GeV/c pp Collisions in the 15-Foot Bubble Chamber; K. Jaeger, et al. Paper submitted to this conference.

6. Inclusive Neutral Particle Production Cross Sections from Copper and Beryllium Targets; Bunce, et al. Abstract submitted to this conference.

7. Private Communication with P. Schlein. Data from UCLA-SACLAY and AACHEN-UCLA-CERN ISR experiments.

8. Data used in Figures 1, 2, and 3 come from papers explicitly referenced and from the following:
   a) Strong Interactions in the NAL Hydrogen Bubble Chamber; Jim Whitmore, Phys. Reports 10C, 273 (1974).
   b) Alston-Garnjost, et al. PRL 35 142 (1975)
      G. Charlton, et al, PRL 29 1759 (1972)
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      E. L. Berger, et al, CERN/D.Ph 11/Phys 74-27
      J. W. Chapman, et al, PL 47B 465 (1973)
      A. Sheng, et al, Fermilab-Pub-74/105-EXP
      H. Blumenfeld, et al, PL 45B 528 (1973).

9. π^-p at 205 GeV/c: Charged and Neutral Multiplicities, Characteristics of Neutral Production; D. Ljung, et al — to be published.

10. P. H. Stuntebeck, et al, Phys. Rev D 9 608 (1974).
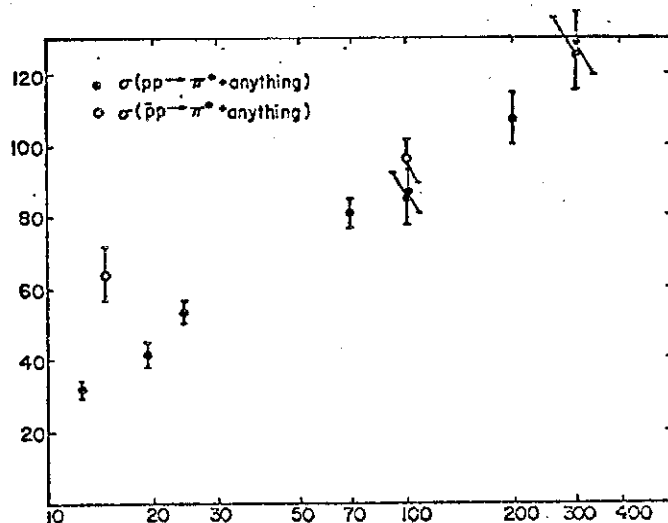
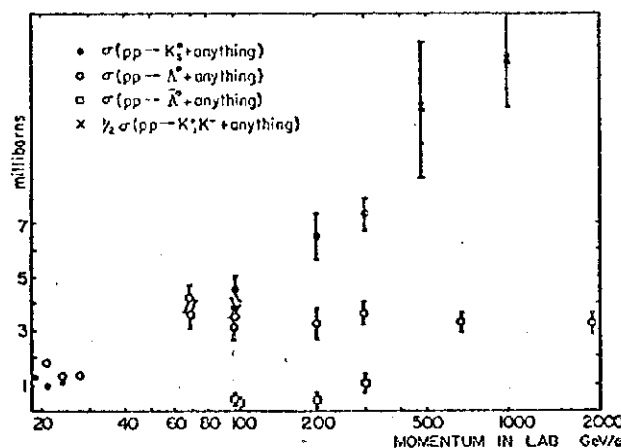Fig. 1 — $\sigma(\pi^O)$ in mb as a function of laboratory momentum of the beam.

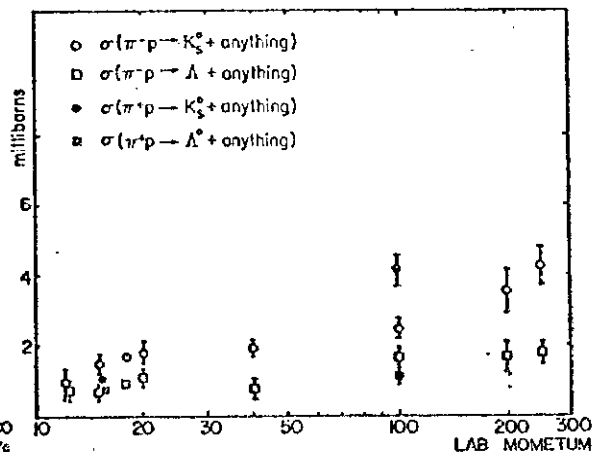Fig. 2 - pp cross sections for neutral production.

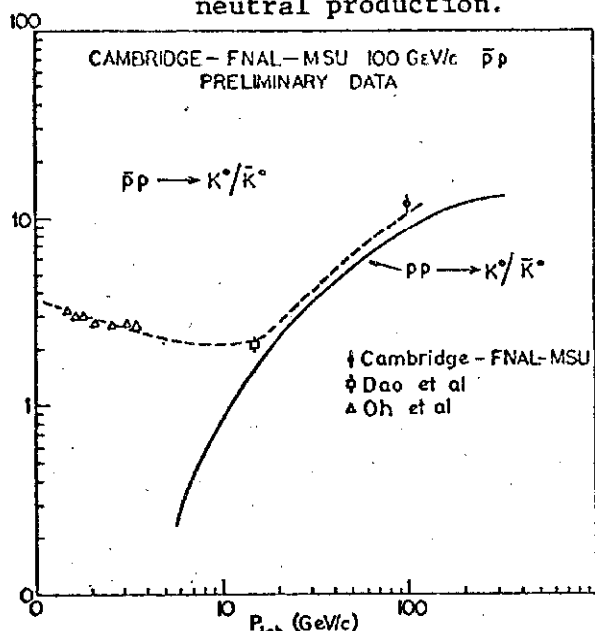Fig. 3 - πp cross sections for neutral production.

Fig. 4 - p̄p cross sections for neutral production.

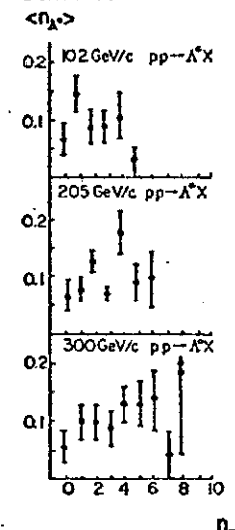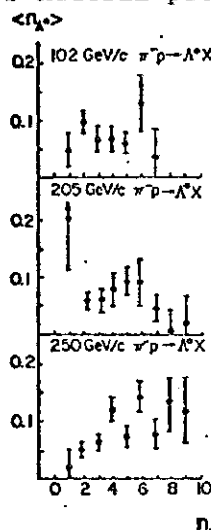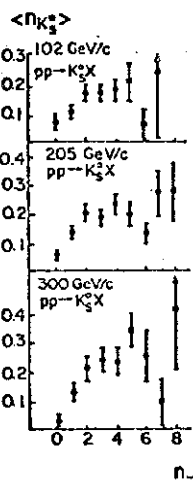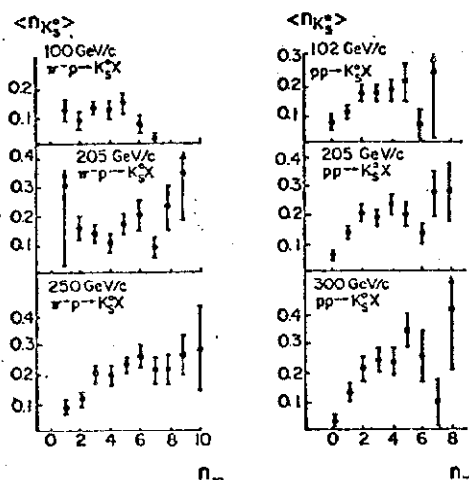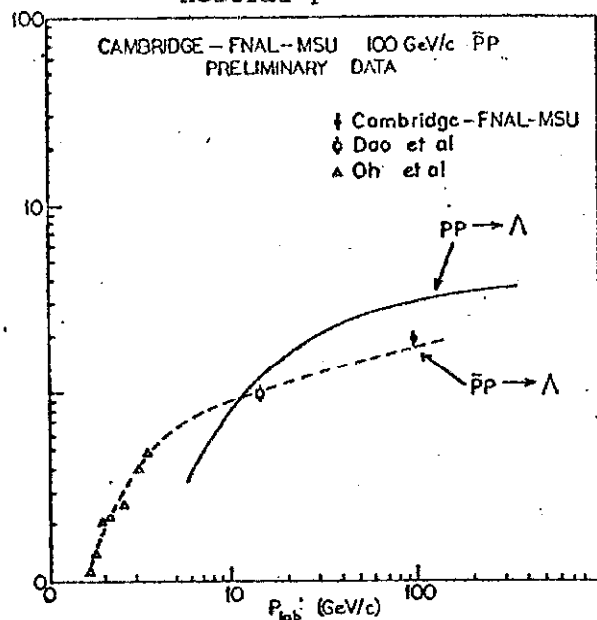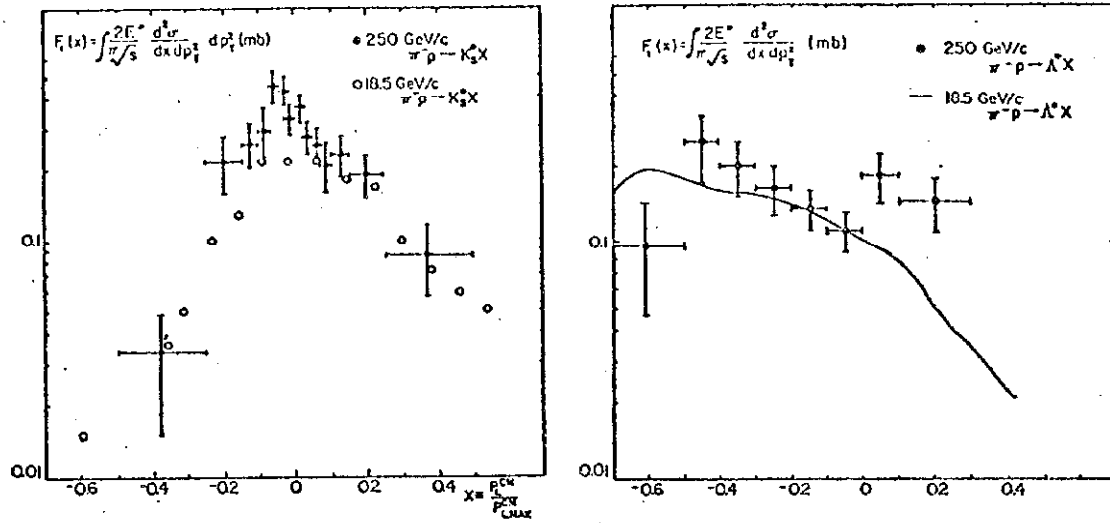Fig. 5 and 6 - Average number of K_s^o and Λ^o vs. number of negative prongs.

Fig. 7 - $F_1(x)$ for $\pi^-p \rightarrow K_S^0 X$ and $\pi^-p \rightarrow \Lambda^0 X$
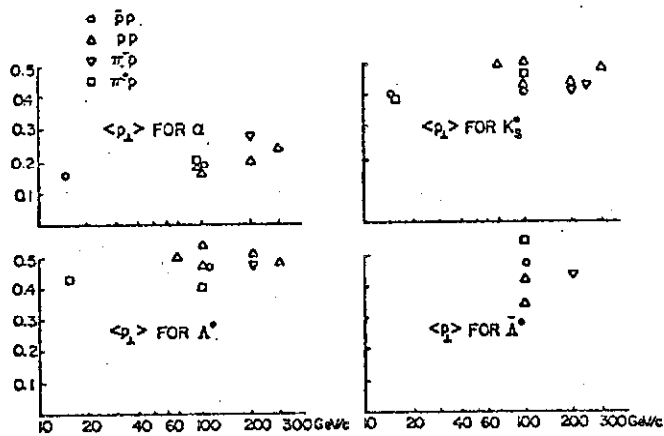

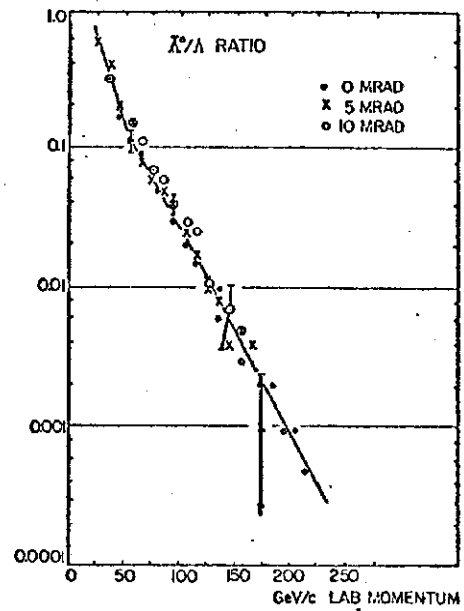Fig. 8 - $\langle P_T \rangle$ for , $K_S^0, \Lambda^0, \overline{\Lambda}^0$

Fig. 9 - $\overline{\Lambda}^0/\Lambda^0$ vs. lab
momentum.
(Wisconsin-Rutgers-Michigan
Data)